CONVERSION OF RAIN RATE DISTRIBUTION FOR VARIOUS INTEGRATION TIME

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ABSTRACT

Rain attenuation can have a serious impact on the availability of radio communication services operating in the frequencies above 10 GHz. For higher frequencies, more rain impairments occur on the communication links. In order to predict reliable rain attenuation for a given location, an appropriate distribution of rainfall rate for the site is required. And further more, the distribution is must be based on long-term (typically more than 10 years) measured data with 1-minute integration time. However, since it is sometimes not possible to collect long-term measured 1-minute rainfall data, an appropriate conversion process for predicting one-minute rainfall rate distribution from that for different integration time is required.

This paper proposes a conversion method for time probability of one-minute rainfall rate from that for integration time great than one-minute. Based on 3-year rain-rate measurements conducted by ETRI, distributions of rainfall rate for 1-, 10-, 20-, 30-, 60-minute integration time are analysed, and relationships between 1-minute and other rainfall data are suggested in this paper.

INTRODUCTION

Rainfall rate data for a given time percentage is required in the prediction of rain attenuation for the time percentage. In accorance with Recommendation ITU-R P.618-6 or P.530-8, the distribution of rainfall rate was deduced from observed rainfall data with 1-minute integration time or less. In usual situtation, however, only a limited number of data sets are available from such measurements. A large amount of rainfall data, typically collected by meteorological agencies in many countries is available for longer integration time, such as 10-min., 20-min., 30-min., etc. To resolve these problems, ITU-R Study Group 3 is recently focudsed on development of a conversion method for rainfall rate distribution for various integration time.

Korea has a lot of long-term(over 10 years) measured rainfall data with 20-minute or 1-hour integration time at several local meteorological agencies. However, it is difficult to obtain 1-minute integrated rainfall data on a long-term basis. Therefore, an effective conversion method for rainfall rate with various integration time is required to predict a reliable 1-minute rainfall rate distribution.

To develop a conversion method, ETRI made an effort to collect rainfall rate data with various integration time using Optical Rain Gauge (ORG) implemented to the rain attenuation measurement system[1]. From the consecutive three-year measurements from July 1998 to May 2001, rainfall rate distributions for several integration time were obtained.

Two kinds of distributions can be considered in the analysis of the measured rainfall data: one is the mean distribution of the three annual statistics and the other is the statistical distribution for the whole measured periods. Figure 1 shows a comparison between the annual mean and the total distribution of rainfall rate for 1-minute integration-time data. Since two distributions in Fig. 1 have very similar characteristics, any one could be used for prediction of 1-min. rainfall rate distribution. In order to obtain rainfall rate value for a shorter time percentage below 0.01 %, however, the total distribution is more preferable. Thus, the total distribution was used in this paper.
For the whole measurement period, the rain rate statistics with various integration time were obtained, and the statistical characteristics are as shown in Figure 2.

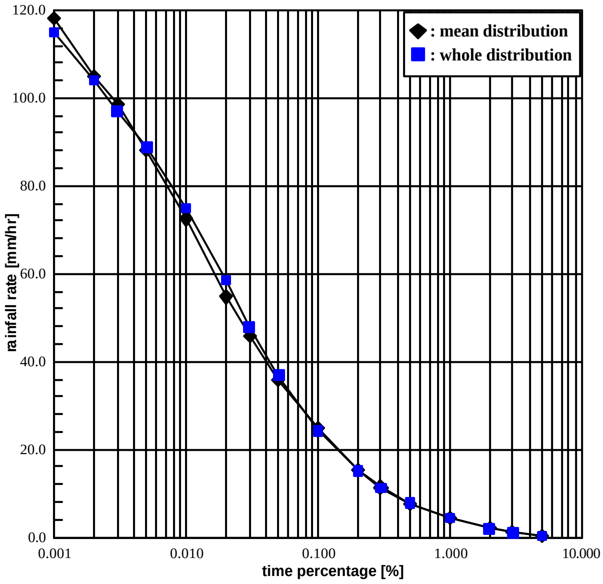

Figure 1. Mean and Total Statistics

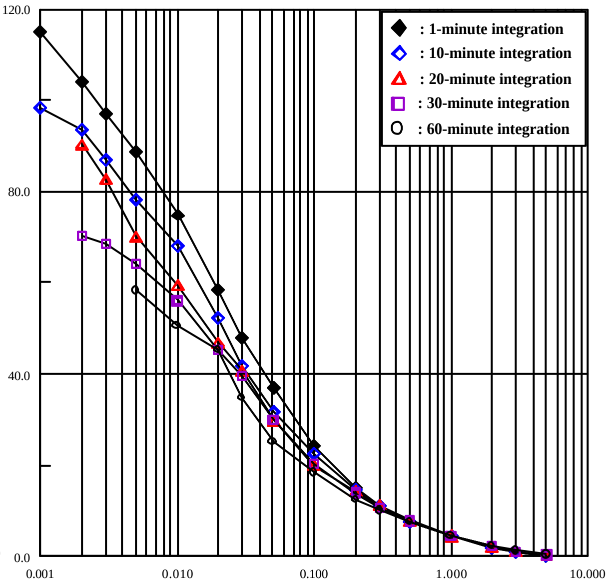

Figure 2. Total Statistics of Rainfall Rate Data for Various Integration Time

RELATIONSHIP BETWEEN EQUI-PROBABLE RAINFALL RATES

There exist some methods of converting 1-minute rainfal distribution from those for different integration-time. The conversion of t-min (normally $t > 1$ minute, in this paper) rainfall rate distributions to equivalent 1-min distribution may be carried out in two different ways:

1) by finding out the relationship of time probability between 1-min and t-min distribution for the same rain rate[2];

2) by obtaining the relationship between 1-min and t-min rain-rates for equal probability[3][4];

Since the latter approach is simpler than the former for the measurement data, the latter case is considered in this paper. In this approach, the relationship between equi-probable rainfall data can be expressed by two different ways: one is treated as a function of their time probability, while the other, as a function of the observed t-min rainfall rate. Even though the expression as a function of t-min rainfall intensity is more general.

In accordance with the equi-probable approach, the relationship have been tested with rainfall data measured at ETRI during three years. Data were analyzed to provide cumulative distributions of rainfall rate with 1, 10, 20, 30, and 60-minute integration time.

Relationship between 1-min and t-min data

Figure 3 shows graphical relations between 1-min and t-min(t = 10, 20, 30, 60 in this paper) rainfall rates in linear scale for given equal probabilities, and Figure 4 shows relations in logarithmic scale. From the Figures, the relationships between 1-min and t-min rainfall rates are likely to be approximated by straight lines with positive slopes and negative interceptions. In addition, the Figures show that logarithmic relations are closer to straight line than linear relations.

Linear regression coefficients for the two relations are shown in Table 1, and simplified regression coefficients for zero interceptions are in Table 2.

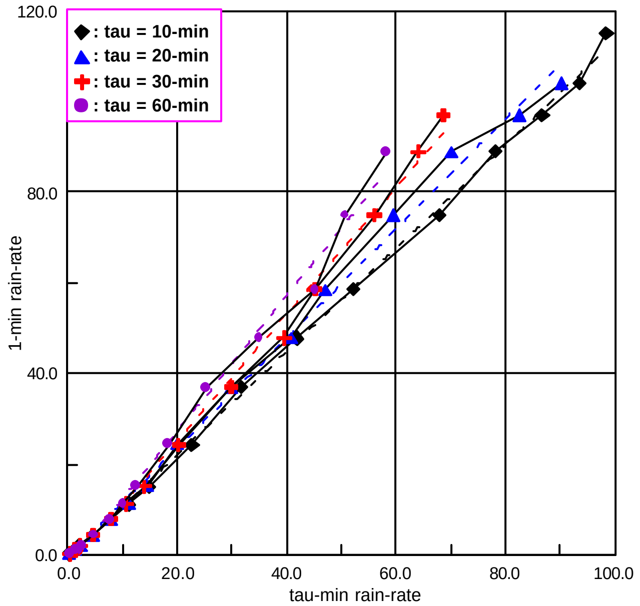

Figure 3. Realtions in linear scale

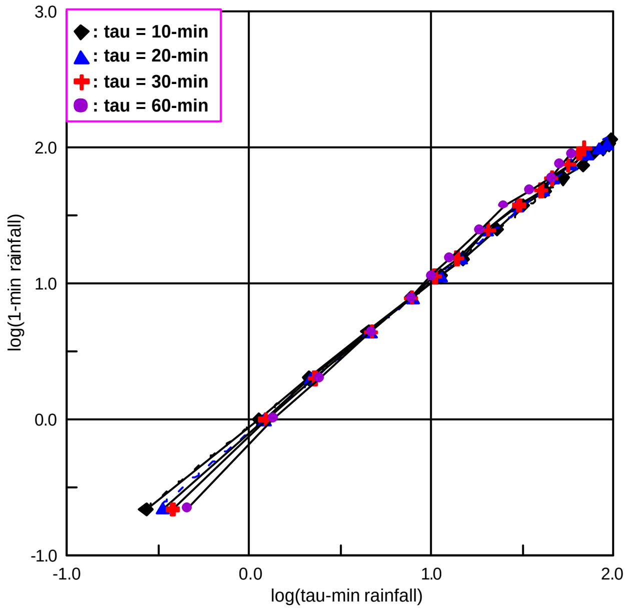

Figure 4. Relations in logarithmic scale

Table 1. Linear regression coefficients for two relations given above

τ [min]	Linear scale			Logarithmic scale		
	slope	intercept	R-squared	slope	intercept	R-squared
10	1.141	-0.819	0.9989	1.059	-0.052	0.9998
20	1.208	-0.584	0.9961	1.105	-0.096	0.9989
30	1.398	-2.820	0.9955	1.151	-0.134	0.9995
60	1.492	-2.570	0.9925	1.217	-0.186	0.9981

Table 2. Regression coefficients for zero interceptions

τ [min]	Linear scale		Logarithmic scale	
	slope	R-squared	slope	R-squared
10	1.129	0.9995	1.028	0.9999
20	1.199	0.9980	1.045	0.9994
30	1.338	0.9977	1.062	0.9997
60	1.426	0.9962	1.084	0.9990

CONVERSION

Using the above regression model based on equal probability, 1-minute rainfall distribution from τ-min distribution could be obtained by the following equations:

$$R_1(p) = aR_t(p) + b, \quad \text{for } 5.0\% \leq p \leq 0.01\%, \text{ (for linear scale)} \tag{1}$$

The logarithmic cases introduce :

$$\log[R_1(p)] = a\log[R_t(p)] + b, \quad \text{for } 5.0\% \leq p \leq 0.01\%, \text{ (logarithmic scale)} \tag{2}$$

The 1-minute rainfall distributions converted from τ-minute measurement data, using equations (1) and (2), are shown in Figure 5 and Figure 6, together with 1-minute measurement data. From the Figures, we can see that the conversion model with zero interception for logarithmic scale shows the best of all. Therefore, we propose the simplified model, given by eq.(2) with values of a in Table 2 and b = 0, as an efficient conversion model for rainfall rate distribution.

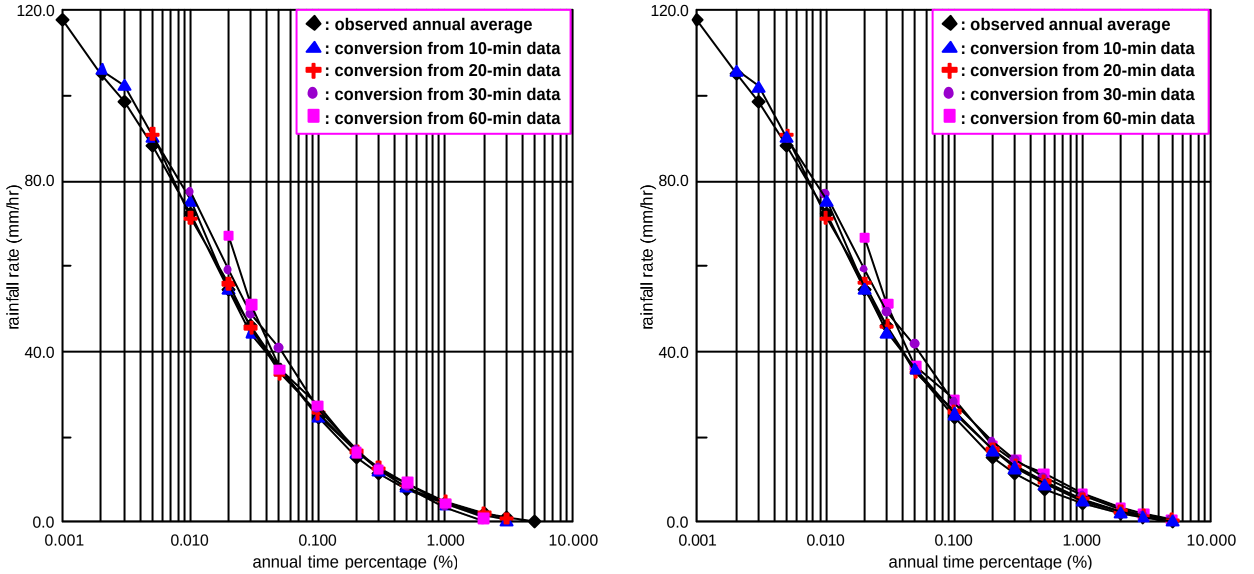

Fig 5. Conversion model for linear scale; non-zero interception(left), zero interception(right)

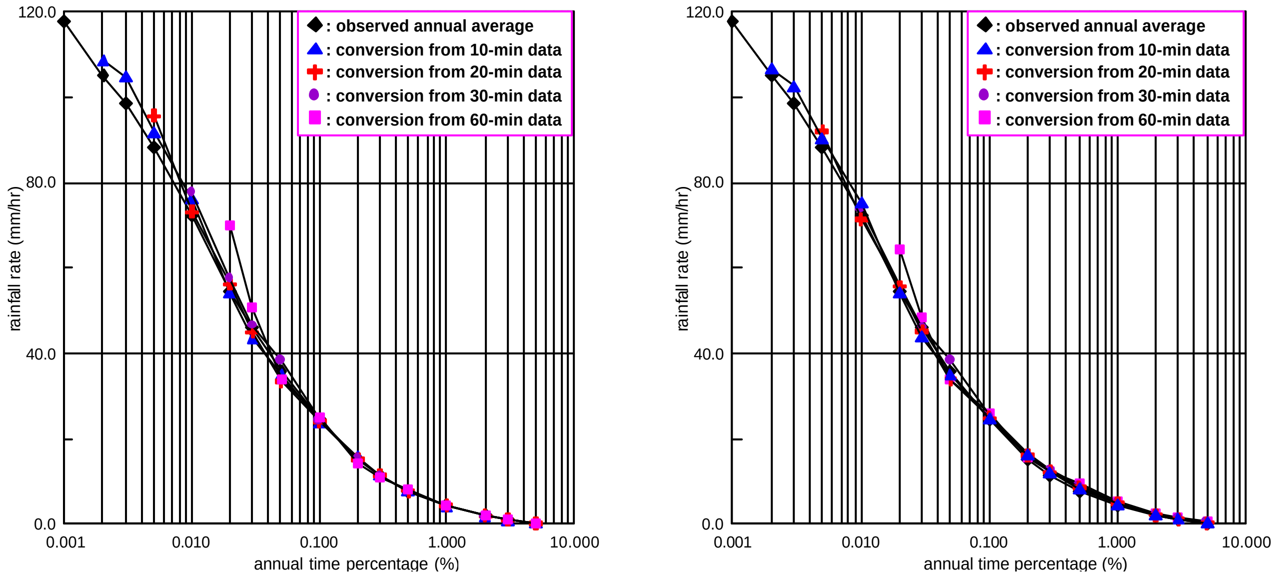

Fig 6. Conversion for logarithmic scale; non-zero interception(left), zero interception(right)

CONCLUSION

A simple conversion method for rainfall rate data with various integration time was proposed based on ETRI's 3-year measurements. It was obtained from the relationship between 1-min and τ-min rainfall data for equal probability. In similar climate zones without long-term (especially, more than 10 years) measured 1-minute rainfall data, the method proposed in this paper can be used to predict rain attenuation on a radio communication paths operating at frequency bands above 10 GHz.

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